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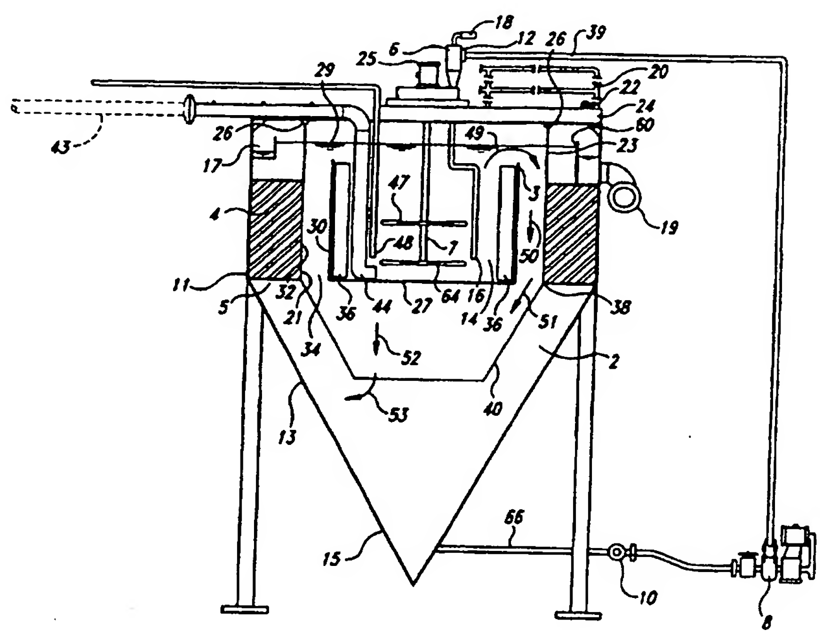

(57) Abstract

A sedimentation device for treating river water, lake water, ground water and other sources of water for human consumption and industrial processes having a mixing chamber, a down-flow zone and an up-flowing clarification zone. The agitation intensity and throughput of the mixing chamber being controlled so as to result in adequate mixing with short residence times.

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WATER TREATMENT SYSTEM

This application is a continuation-in-part of U.S. Application Serial No. 08/661,409, filed June 7, 1996, which is a continuation of U.S. Application Serial No. 08/621,317, filed March 25, 1996.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention generally relates to gravitational separation by sedimentation and, more particularly, to systems for continuously separating suspended solid materials from a feed stream by gravity settling.

STATE OF THE ART

Sedimentation devices which incorporate settling tanks are well known to separate suspended solids from streams of liquid, such as ground water, process water, creek water, stream and river water and lake water, by gravity settling. To increase the effectiveness of the liquid-solid separation, it is well known to employ various chemical flocculating agents (e.g., polyelectrolyte polymers) and coagulating agents (e.g., mineral salts). When mixed with the influent, the agents combine with suspended solids to form rapidly settlable aggregates, called floc.

It is also known that settling of floc particles can be enhanced in certain circumstances by mixing the flocculating agents with inert particles such as sand. Typically, the mixing of flocculating agents and inert particles with the influent is accomplished outside the sedimentation (or settling) tank proper, say in a pipe or mixing chamber and, may be accompanied by mechanical stirring of the mixture to provide contact opportunity and time for the resulting flocs to grow.

DEFINITIONS

TURBIDITY in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and

plankton and other microscopic organisms. Turbidity is an expression of the optical properties resulting from light being scattered and absorbed rather than transmitted in straight lines through the water. Turbidity is measured with nephelometric measurements and compared using nephelometric turbidity units (NTU) which are basically a comparison of the intensity of light scattered by a sample of water in question with a standard reference suspension.

COLOR in water is comprised of "apparent color" which results from a combination of soluble and suspended impurities and "true color" which is a measurement of only the color resulting from soluble impurities after the suspended material has been filtered out. True color usually results from metallic ions such as iron and manganese. Color is measured in "color units" which is a comparison of a water sample with a standard sample which has a value of zero.

SUMMARY OF THE INVENTION

The present invention, in very general terms, provides a sedimentation device for treating water having a mixing chamber with at least two impellers, a down flow zone and an up-flowing clarification zone. The input and the mixing characteristics of the mixing chamber being controlled so as to require short residence time in the mixing chamber of the influent being treated.

More particularly, the present invention provides an improved sedimentation device for treating water, such as but not limited to ground water, process water, creek water, stream and river water, lake water, and the like, (as opposed to waste water, such as mineral slurries, ore slurries, pulp and paper recausticizing slurries, flue gas scrubbing slurries, coal refuse slurries, and municipal and industrial wastes and sewage) in which the water is in the mixing chamber for a short time while still providing good clarity in the clarified effluent. Influents which the sedimentation device of the invention is intended to treat include all sources from which potable water can be obtained by treating the influent to remove color and insoluble sediments detrimental to human consumption.

In one aspect of the present invention, there is provided a process for influent liquid treatment by sedimentation by combining a flow of pretreated influent, flocculant and inert particles in a solids contact chamber with at least two impellers for or about 180 seconds or more to produce a flocculated mixture, passing the flocculated mixture from the solids contact chamber into a down-flow zone, passing the flocculated mixture through the down-flow zone, without further mechanical agitation, into a settling zone and removing the clarified influent from an upper region of the settling zone and settled flocs and other settled materials from a lower region of the settling zone.

In another aspect of the present invention, there is provided an apparatus for influent treatment by sedimentation having a solids contact chamber having a pretreated influent inlet, a flocculant inlet, an inert particles inlet and at least two impellers to produce a flocculated mixture, a settling zone below the solids contact chamber having a settled flocs and other settled materials outlet, a down flow zone connecting the solids contact chamber to the settling zone such that the down-flow zone passes the flocculated mixture from the solids contact chamber into the settling zone without mechanical agitation, and a clarification zone above the settling zone.

In another aspect of the present invention, there is provided a process for influent liquid treatment by sedimentation by combining a flow of pretreated influent, flocculant and inert particles in a solids contact chamber with at least two impellers for about 180 seconds or more to produce a flocculated mixture, passing the flocculated mixture from the solids contact chamber into a down-flow zone, passing the flocculated mixture through the down-flow zone utilizing differential sedimentation into a settling zone and removing the clarified influent liquid from an upper portion of the settling zone and removing settled flocs and other settled materials from a lower region of the settling zone.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects of the present invention can be readily ascertained from the following detailed description and appended drawings, which are

offered by way of example only and not in limitation of the invention, the scope of which is defined by the appended claims and equivalents. In the drawing:

Figure 1 is a cross-sectional view of a sedimentation device in accordance with one embodiment of the present invention, parts of which are shown schematically;

Figure 2 is a cross-sectional view of a sedimentation device in accordance with another embodiment of the present invention, again with parts shown schematically;

Figure 3 is a graph showing the reduction in the color as a function of mixing time for highly colored well water;

Figure 4 is a graph showing the reduction in turbidity as a function of mixing time for the same highly colored well water of Figure 3;

Figure 5 is a graph showing the reduction in the color as a function of mixing time for creek water;

Figures 6 and 7 are graphs showing the impact of inert particle carriers on turbidity and color; and

Figure 8 is a graph showing the impact of G value on turbidity as a function of flocculation time.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The sedimentation devices of each of the embodiments shown in Figures 1 and 2 include a settling tank or main vessel 2 in which separation by sedimentation principally occurs utilizing ballasted flocculation. Preferably, the settling tank 2 is cylindrical in configuration, but a rectangular or other shaped configuration can be used.

In the embodiment illustrated in Figure 1, vessel 2 is defined by a sidewall 11 and a bottom wall 13. Preferably, bottom wall 13 slopes downward at an angle in the range of or about 50° to or about 70° toward a collection cone 15 formed centrally in the bottom wall 13 of the tank 2 to prevent any sludge from building up on the bottom wall 13 as the flocs settle in the settling tank 2. For larger settling tanks

(FIG. 2), a sloping bottom wall 13 of any angle from 0° to 15° is used in combination with a raking mechanism 37.

As further shown in Figures 1 and 2, a collection system (e.g., launder) 17 is mounted in the sidewall 11 of the vessel 2. The collection system includes an outlet pipe 19 and an overflow weir 60, which defines the liquid level 29 in the tank 2. Centrally disposed in the tank is a generally cylindrical vessel 23 which for purposes of identification herein will be referred to as a down-flow vessel. The down-flow vessel 23 can be supported from the bridge 24 as shown (or other trusswork which traverses the tank) or can be supported by extensions (not shown) extending inwardly from the inner walls of the settling tank 2. (Bridge 24 can be provided with handrail 20 and lifting lugs 22.) In operation of the sedimentation system, the down-flow vessel 23 serves to partition the settling flocs and treated water from the clarified effluent rising along the sides of the settling tank 2. Attached to the lower portion 21 of the down-flow vessel 23 at junction 38 is truncated cone 40. Although cone 40 is not necessary in all circumstances, it assists in bringing the settled flocs to the center of the settling tank 2 for more efficient collection by collection cone 15.

Also supported from bridge 24 is solids contact or mixing chamber 14. Preferably, solids contact chamber 14 is supported by adjustable hangers 26 and comprises an upwardly or downwardly telescoping section that allows the volume of the solids contact chamber 14 to be controllably varied depending on the operating needs. It can now be appreciated that the outer surface 30 of chamber 14 and the inner surface 32 of down-flow vessel 23 define a down-flow zone 34; the function and operation of the down-flow zone 34 will be described in more detail below.

Baffle plates/vortex breakers 36 can optionally be mounted in the solids contact chamber 14. The baffle plates 36 are vertically mounted at four spaced-apart positions within the solids contact chamber 14 and extend radially across the vessel for 1/12 to 1/10 the diameter of the solids contact chamber. In operation, the baffles prevent disruptive vortexes or swirls from being established in the solids contact chamber that might break up the flocs or entrap air. Typically, four baffles are provided, but the number and configuration of the plates is a matter of design choice.

As still further shown in Figures 1 and 2, at least one inlet feed 43 is provided in fluid communication with the interior of the solids contact chamber 14. By way of inlet feed 43, a stream of influent is fed in to the interior of chamber 14 through a distributor 44. In operation of the system, the distributor 44 is sized relative to the influent flow rate to distribute the influent evenly in the solids contact chamber. Above the outlet of distributor 44 is mounted a mixing impeller 47 and lower in the chamber 14 adjacent the outlet of distributor 44 is a lower impeller 64. Preferably two impellers are used as shown. Upper impeller 47 is preferably either a marine or hydrofoil type impeller which provides gentle mixing for additional flocculation time without destroying the flocs already formed. The upper impeller 47 maintains suspension of the flocs and inert particles prior to their transport out of the chamber 14. Lower impeller 64 is preferably a turbine type impeller which provides higher speed/higher shear mixing. The impellers 47 and 64 coupled to the drive unit 25 through shaft 7 or to an auxiliary rotary drive (not shown). Also located near the impeller 64 in the solids contact chamber 14 is an outlet 16 which, as will be explained in greater detail below, injects recycled inert particles into the chamber from a hydrocylcone underflow. Still further, a polymer or flocculating agent injection outlet 48 is located near the impeller 64 in the solids contact chamber 14. In practice, it is particularly advantageous to introduce the inert particles and flocculant as close together as possible so that the flocculant and inert particles come together quickly. In one embodiment, the inert particles and flocculant are injected together in an inlet feed stream. The inert particles employed in the system are typically 150 micrometers in diameter or less, but should be sufficiently large to maintain a relatively high settling velocity in the down flow zone after flocs have formed around them. The inert particles also aid in taking advantage of the differential sedimentation phenomena based on the heterogenous curvilinear flocculation theory.

Impeller 64 is rotated to provide just enough agitation to produce sufficient mixing of the suspended solids with the influent, inert particles and flocculant to promote the formation of flocs without inducing shear that would break the formed flocs apart. Impeller 47 is operated to impart just enough turbulence to maintain the

solids in suspension with as little shear as possible as flocs are forming. The mixing in mixing chamber 14 advantageously utilizes the differential sedimentation phenomena for floc production with the addition of the inert particles. Thus, the flocs and treated water that overflow the top edge 3 of the solids contact chamber 14 into the down flow zone 34 are generally uniformly mixed. Lower impeller 64 provides higher velocity gradient (G) values, compared to the upper impeller 47, in the initial mixing area to induce floc formation. Upper impeller 47 provides more gentle mixing to provide additional flocculation time without destroying the flocs already formed. Although, two impellers are shown, it is within the scope of the invention to use more than two impellers to induce floc formation in the lower portion of mixing chamber 14 and to provide more gentle mixing in the upper portion. When more than two impellers are used, the impellers between the lower impeller and upper impeller can be turbine, marine or hydrofoil type impellers, likewise the velocity gradient values can be varied by the tip speed or shape of the impellers to provide the desired mixing conditions. At this juncture, it should be appreciated that the solids contact chamber 14 is designed and sized to provide short residence times and that the hydraulic velocities aid in keeping the inert particles suspended. The impellers 47 and 64 provide uniform mixing of the flocculant, influent and inert particles over the range of normal load operations.

As the flocs and treated influent overflow the top edge 3 of the solids contact chamber 14, the fluid velocity changes from about 150 meters/hour at arrow 49 to about 50 meters/hour at arrow 50. The velocities through the down flow zone 34 generally are dependent upon the relative diameters of the solids contact chamber 14 and the down-flow vessel 23, at least to a first-order approximation. In practice, the relative diameters of the solids contact chamber 14 and the down-flow vessel 23, are sized such that the down flow velocities are relatively high without creating shear in the liquid that would break up the flocs. After the flocs and treated influent pass below the bottom wall 27 of the solids contact chamber, the fluid flow velocity decreases at arrow 51, accelerates in the space of truncated cone 40 at arrow 52 and then decelerates as the flow exits truncated cone 40 at arrow 53. Outside of the down-flow vessel 23, the

clarified effluent rises in clarification zone 5 and through the settling plates 4 (e.g., at a velocity about 20 meters/hour and higher) and, finally, overflows into the launder 17.

With regard to the embodiment shown in Figure 2, drive unit 25 of conventional construction is mounted on the bridge 24 to drive the impeller 47, impeller 64, and optional raking mechanism 37. (The rotation rates of the two impellers and raking mechanism can, of course, be different; typically, the impellers rotate at a much faster rate than the raking mechanism.) In the illustrated embodiment, the raking mechanism 37 is of conventional construction and is mounted to rake settled solids across the bottom or floor 13 of the tank to the collection cone 15 such that no sludge build up occurs on the bottom wall. In the illustrated embodiment, an optional deflection cone 9 is connected to the shaft 7 for rotation. Sludge scraper 60 attached to shaft 7 below bearing 62 rotates within collection cone 15 to prevent the build up of sludge in the cone.

From the collection cone 15 in either Figure 1 or Figure 2, settled solids and inert particlesare pumped to inlet 12 of separation device 6 (e.g., hydrocyclone) via conduit 39 by high shear recirculation pump 8. Pump 8 withdraws the settled solids and inert particles from the collection cone 15 through conduit 66 at a sufficient rate to remove the inert particles and settled solids. In some operations, pump 8 prevents a build up of sludge in the bottom of the settling tank or in the collection cone. In operation, high shear pump 8 breaks the bonds between the sludge and inert particles to assist the separation device 6 in separating the inert particles, which are recycled into the solids contact chamber 14 through separating device underflow 16, and the sludge which is discharged through outlet 18 of separating device 6. A flush-out connection 10 can be provided in conduit 66.

Concomitant with the removal of thickened, settled solids via the collection cone 15, clarified effluent is removed at the liquid surface 29 in the settling tank 2 via the launder 17 and launder outlet 19. Various suitable launder arrangements which can be used in the present invention are well known in the sedimentation art.

In summary to this point, the interior of the settling tank 2 can be understood to comprise a zone for receiving and mixing the stream of influent, inert

particles and flocculant; a down-flow zone with no mechanical agitation and/or no or very little shear for directing clarified liquid and flocs to the bottom of the settling tank; and an up-flow zone in which clarified liquid is withdrawn. The inert particles are recycled from the sediment (i.e., sludge) collected at the bottom of the clarification zone and the re-introduced (i.e., recycled) inert particles are normally provided from the separation device after being separated from the mixture of settled solids and inert particles that were previously removed from the settling vessel 2.

At this juncture, it can be appreciated that the above-described sedimentation device is a unique combination of a chemical reactor and clarifier within a single vessel. It is a compact unit that can be used in a liquid-solid separation process with an improved separation efficiency (i.e., high capacity) due to short residence times in the solids contact chamber 14. The improved separation efficiency is due as much to the high settling rates in the clarification zone as it is to the short residence times in the solids contact chamber. These two principles work together. The inert particles increase the flocculation rate resulting in a short residence time and a small mixing chamber. The high settling rate resulting from the use of the inert particles and polymer greatly reduces the necessary size of the clarification zone. One feature of the process is the introduction of inert particles in the chemical treatment process which are recovered and recycled within the system. The inert particles, with high specific gravity, function as nuclei for binding with fine suspended solids by a long chain polyelectrolyte to produce large and dense flocs. The flocs formed in such a way settle rapidly and are easily separated from the liquid phase. The inert particles also work as a flocculation aid and provide a large surface area that substantially increases the probability of particle collision, speeding the agglomeration of the flocs and enhancing separation efficiency. As a direct consequence, the overall size of the clarifier is significantly reduced and the capital equipment costs are reduced. In the following, various process steps will be described employing the above-described sedimentation device.

PROCESS STEP 1

Pre-treatment of influent (e.g., to screen, adjust pH, add coagulant and to provide other chemical/physical conditioning) as required. In each water treatment

application the influent is analyzed and pretreatment is provided based on what is required to bring the influent into a normal processing range.

PROCESS STEP 2

The solids contact chamber 14 is used to bring the influent to be treated, the chemical flocculant, and the inert particles together in a controlled manner which results in rapid flocculation of suspended solids which then overflow into the down-flow zone 34. The short residence time in the solids contact chamber preferably in the range of or about 180 seconds to or about 480 seconds, more preferably of or about 360 seconds or more, results in much smaller equipment requirements to accomplish an equivalent level of water purification. The reactions, both chemical and physical, which occur in the solids contact chamber 14 are controlled to provide adequate mixing and contact of the suspended solids with the flocculant to provide flocs. The mixing is not so turbulent or long lasting so as to break up the delicate flocs produced. Adequate but not excessive mixing and adequate but not excessive residence time are based on the influent characteristics and coagulation mechanisms.

Examples of the process variables and/or characteristics are listed in the following Table I. All of the values are approximate and therefore may be greater or less for any particular operating process. The range provided for each of these variables and/or characteristics allows for adjustment in the process depending on variations in influent flow rate which affects residence time and therefore the other mixing characteristics which are adjusted accordingly, for example, lower flow rates require lower amounts of inert particles and result in longer residence times. Therefore, tip speeds would be reduced to lower the velocity gradient values. Likewise, the ranges given allow for adjustments due to larger mixing systems and designs which are affected by other factors (such as impurities, temperature, etc.) in addition to the mixing requirements, for example, ranges in impeller sizes and distances from the surface and the bottom of the mixing chamber allow for optimization of tip speed and velocity gradient values.

Table I

	Nominal	Range
residence time in solids contact chamber (seconds)	360	180 to 480
inert particles added (grams/liter of influent)	3 to 5	1 to 100
flocculant added (mg/liter of influent)	0.2	0.05 to 5.0
mixing characteristics lower impeller D/T, impeller	0.7	0.55 to 0.8
distance from bottom of mixing chamber	0.33T or 0.5D	0.3T to 0.5T or 0.4D to 0.6D
impeller tip speed (m/sec)	2.25	1.0 to 3.5
velocity gradient, G (sec^{-1})	750	500 to 1000
upper impeller D/T, impeller	0.5	0.45 to 0.6
distance from surface of water in mixing chamber	0.75D	0.75D to 1.5D
impeller tip speed (m/sec)	1.8	0.5 to 2.5
velocity gradient, G (sec^{-1})	300	100 to 600

PROCESS STEP 3

The down-flow zone 34 in the sedimentation device provides a transportation path into the settling tank free of mechanically induced turbulence and no or a minimum of shear for the flocs and treated influent mixture. The operational parameters on this step are such that (a) no turbulence is induced and any shear which occurs does not destroy the flocs and (b) that the path to the settling tank is downward and efficient. In the systems having a circular cross-section shown in Figures 1 and 2, this zone is around the outer surface 30 of the solids contact chamber 14 and is surrounded by the inner surface 32 of down-flow vessel 23. Down-flow vessel 23 prevents "short circuiting" of the flocs and treated influent to the clarification zone 5. In

a rectangular system (not shown) this zone is rectangular or circular. There is no particulate suspension or mixing required or induced in the down-flow zone. The treated influent and flocs pass through the down-flow zone without further mechanical agitation.

The configuration of the down-flow zone 34 insures that the treated influent and flocs pass downward to the bottom of the settling tank 2 without substantial deleterious turbulence or shear. Typically, flow rates of less than 60 meters/hour are maintained in this transition region so that the flocs are not destroyed.

PROCESS STEP 4

The clarification zone 5 can operate with or without separator, lamella plates 4 or tube settlers. In the system without lamella plates, a rise rate of 20 meters/hour or higher can be used compared to rise rates of 1 to 2 meters/hour in conventional system clarifiers. The higher rise rates for this system compared to the conventional system result primarily from the use of the inert particles and polymer added to the influent. The use of lamella plates can be used to increase the capacity of the system with rise rates exceeding about 100 meters/hour. The upper part of the clarification zone 5 contains a collection system 17 for directing the clarified effluent to the system outlet 19. The sludge sedimented from the influent is collected at the bottom of the collection cone 15 and pumped to a separation device 6.

PROCESS STEP 5

The sludge/inert particle separation operation separates the inert particles from the sludge using a high shear recirculation pump 8 to transport the sludge mixture to the separating device 6. The inert particles are then recycled into the solids contact chamber 14 to be reused. The sludge is transported out of the system to be disposed of using known devices such as a belt press.

TESTS

Test results demonstrating the effectiveness of the present invention on color and turbidity as a function of mixing time are shown in Figures 3-5. Figures 6 and 7 show the effect of different size inert particle carriers used in accordance with the

present invention on color and turbidity. Figure 8 illustrates the optimization of the mixing characteristics and residence time to achieve turbidity reduction in accordance with the present invention.

Modifications and variations of the present invention will be apparent to those having ordinary skill in the art having read the above teachings, and the present invention is thus limited only by the spirit and scope of the following claims.

What is Claimed is:

1. A process for influent liquid treatment by sedimentation, comprising:

combining a flow of pretreated influent, flocculant and inert particles in a solids contact chamber with at least two impellers for about 180 seconds or more to produce a flocculated mixture;

passing the flocculated mixture from the solids contact chamber into a down-flow zone;

passing the flocculated mixture through the down-flow zone, without further mechanical agitation, into a settling zone; and

removing clarified influent liquid from an upper region of the settling zone and removing settled flocs and other settled materials from a lower region of the settling zone.

2. The process of Claim 1 further comprising:

separating the inert particles from the settled flocs and other settled materials; and

recycling the inert particles into the solids contact chamber.

3. The process of Claim 1 wherein the pretreated influent, flocculant and inert particles are resident in the solids contact chamber for a period of time in the range of about 180 seconds to about 480 seconds.

4. The process of Claim 1 wherein the pretreated influent, flocculant and inert particles are subjected to agitation in the solids contact chamber sufficient to produce mixing of the influent, flocculant and inert particles to form the flocs without inducing shear that breaks apart the flocs.

5. The process of Claim 1 wherein the pretreated influent, flocculant and inert particles are combined utilizing differential sedimentation for floc production.

6. The process of Claim 1 wherein the combining step comprises: rotating a first impeller of the at least two impellers so as to provide sufficient agitation to produce sufficient mixing of the pretreated influent, flocculant and inert particles to promote the formation of flocs; and rotating a second impeller of the least two impellers so as to maintain forming flocs in suspension.

7. The process of Claim 6 wherein the first impeller is rotated to produce a velocity gradient value in the range of about 500 to about 1000 and the second impeller is rotated to produce a velocity gradient value in the range of about 100 to about 600.

8. Apparatus for influent treatment by sedimentation, comprising:

a solids contact chamber having a pretreated influent inlet, a flocculant inlet, an inert particles inlet and at least two impellers to produce a flocculated mixture;

a settling zone below the solids contact chamber having a settled flocs and other settled materials outlet;

a down-flow zone connecting the solids contact chamber to the settling zone such that the down-flow zone passes the flocculated mixture from the solids contact chamber into the settling zone without mechanical agitation; and

a clarification zone above the settling zone.

9. The apparatus of Claim 8 wherein: a first impeller of the at least two impellers located in the solids contact chamber which imparts just sufficient agitation in the solids contact chamber to produce sufficient mixing of the influent, flocculant and inert particles to form the flocs; and a second impeller which maintains forming flocs in suspension.

10. The apparatus of Claim 8 wherein the inlets for the influent, inert particles and flocculant are in close proximity.

11. The apparatus of Claim 8 wherein the volume of the solids contact chamber can be varied by telescoping a portion of the solids contact chamber.

12. The apparatus of Claim 8 further comprising a recirculation system.

13. The apparatus of Claim 8 further comprising a high shear pump separation device.

14. The apparatus of Claim 8 wherein the at least two impellers comprise:

a first impeller of the at least two impellers which produces a velocity gradient value in the range of about 500 to about 1000; and a second impeller of the at least two impellers which produces a velocity gradient value in the range of about 100 to about 600.

15. The apparatus of Claim 8 wherein the at least two impellers comprise:

an upper marine or hydrofoil type impeller; and

a lower turbine type impeller.

16. A process for influent liquid treatment by sedimentation, comprising:

combining a flow of pretreated influent, flocculant and inert particles in a solids contact chamber with at least two impellers for about 180 seconds or more to produce a flocculated mixture;

passing the flocculated mixture from the solids contact chamber into a down-flow zone; passing the flocculated mixture through the down-flow zone utilizing differential sedimentation into a settling zone; and removing the clarified influent liquid from an upper region of the settling zone and removing settled flocs and other settled materials from a lower region of the settling zone.

17. The process of Claim 16 further comprising:

separating the inert particles from the settled flocs and other settled materials; and

recycling the inert particles into the solids contact chamber.

18. The process of Claim 16 wherein the pretreated influent, flocculant and inert particles are resident in the solids contact chamber for a period of time in the range of about 180 seconds to about 480 seconds.

19. The process of Claim 16 wherein the pretreated influent, flocculant and inert particles are subjected to agitation in the solids contact chamber sufficient to produce mixing of the influent, flocculant and inert particles to form the flocs without inducing shear that breaks apart the flocs.

20. The process of Claim 16 wherein the combining step comprises: rotating a first impeller of the at least two impellers so as to provide sufficient agitation to produce sufficient mixing of the pretreated influent, flocculant and inert particles to promote the formation of flocs; and

rotating a second impeller of the least two impellers so as to maintain forming flocs in suspension.

21. The process of Claim 20 wherein the first impeller is rotated to produce a velocity gradient value in the range of about 500 to about 1000 and the second impeller is rotated to produce a velocity gradient value in the range of about 100 to about 600.

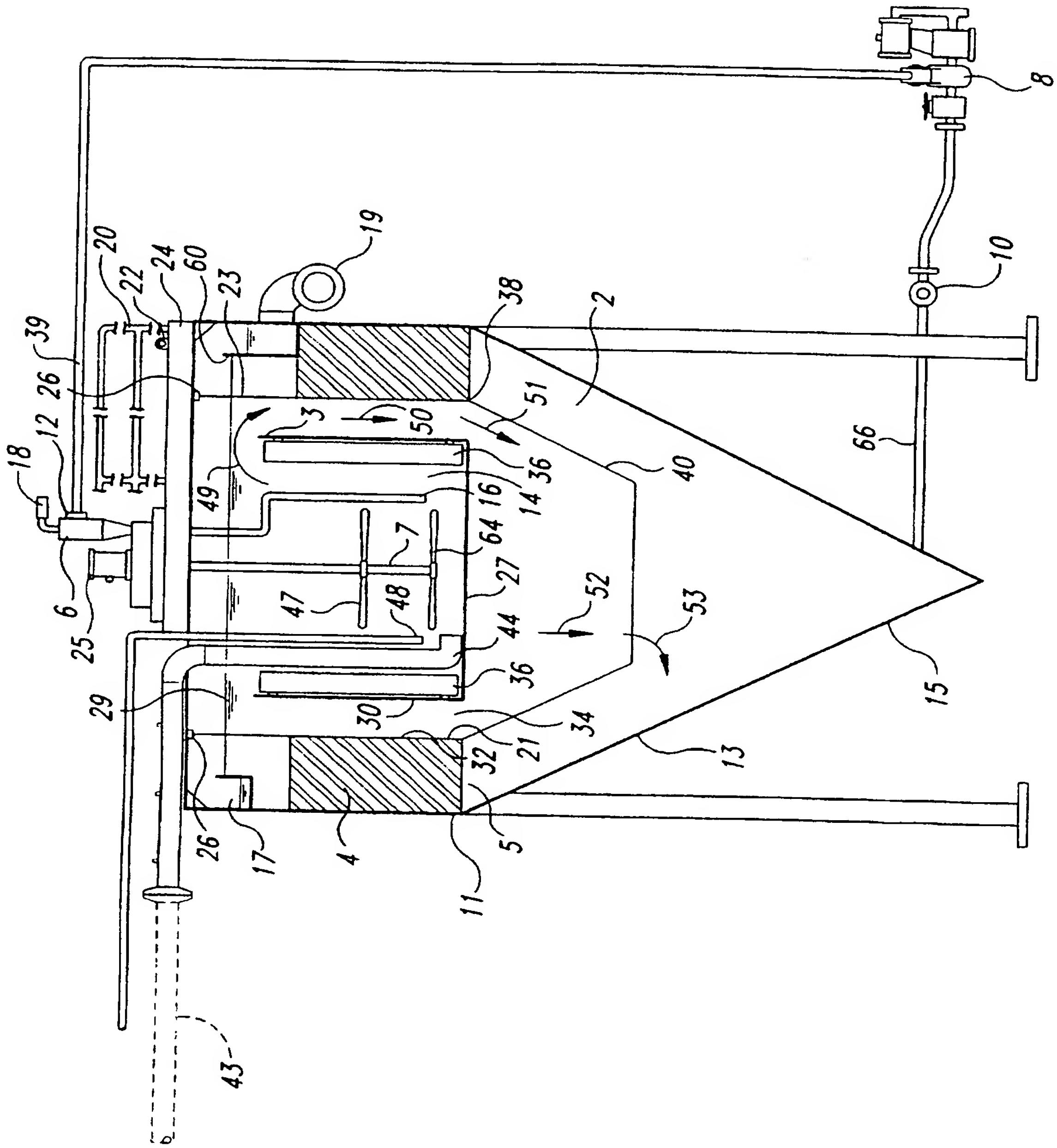
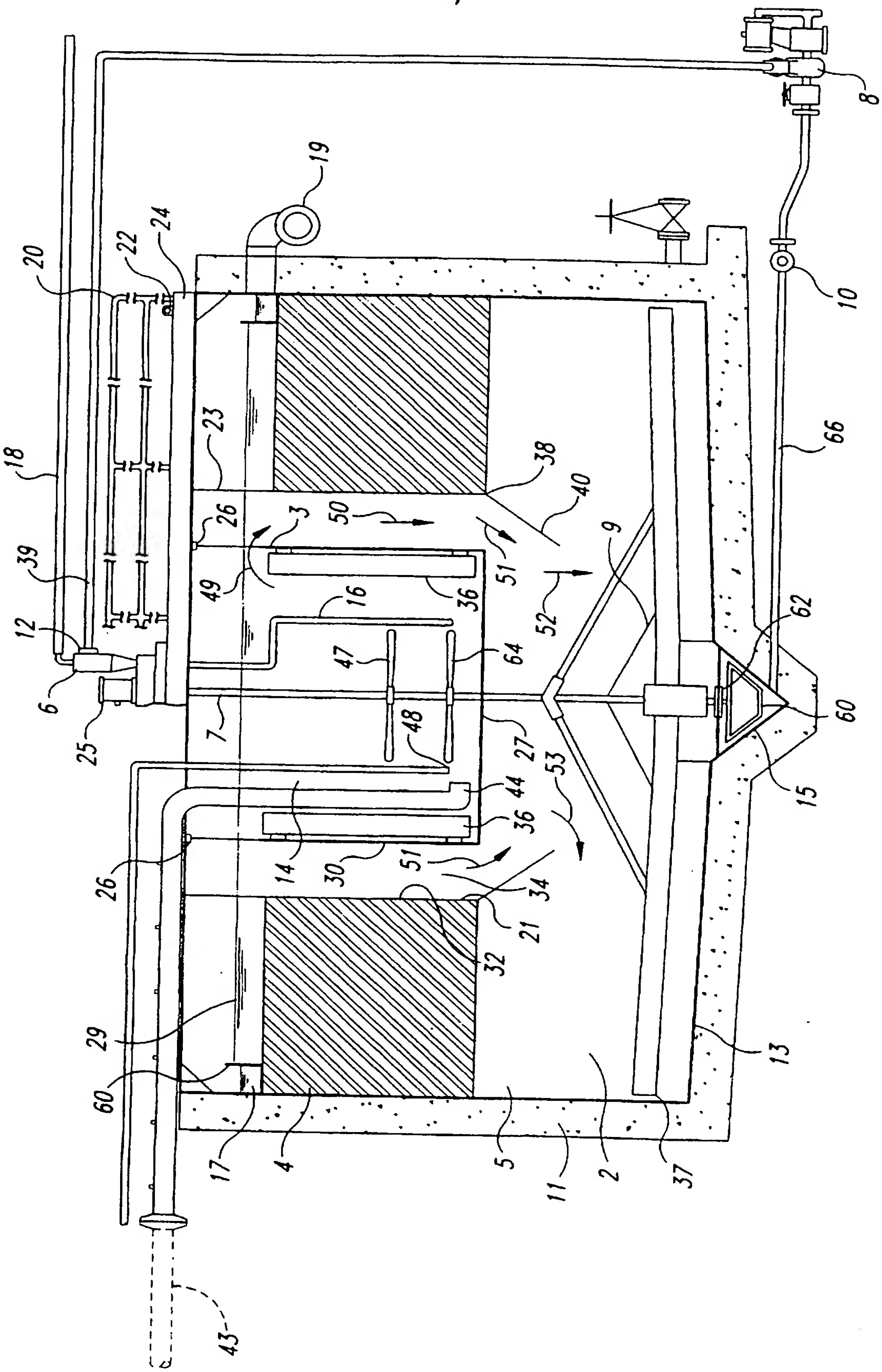


Fig. 1

SUBSTITUTE SHEET (RULE 26)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3
4
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9
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11
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51
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52
53
60
60
62
64
66

Fig. 2

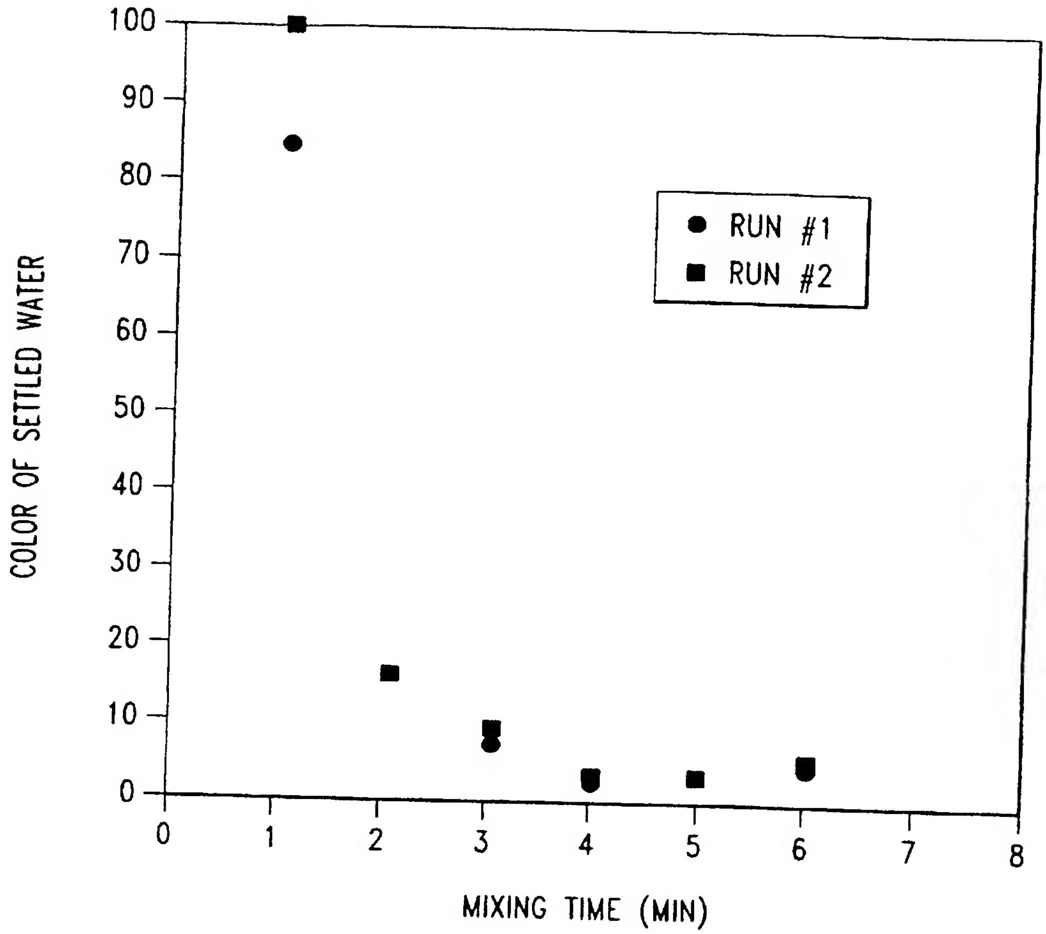

100
90
80
70
60
50
40
30
20
10
0
COLOR OF SETTLED WATER
0
1
2
3
4
5
6
7
8
MIXING TIME (MIN)
RUN #1
RUN #2

Fig. 3

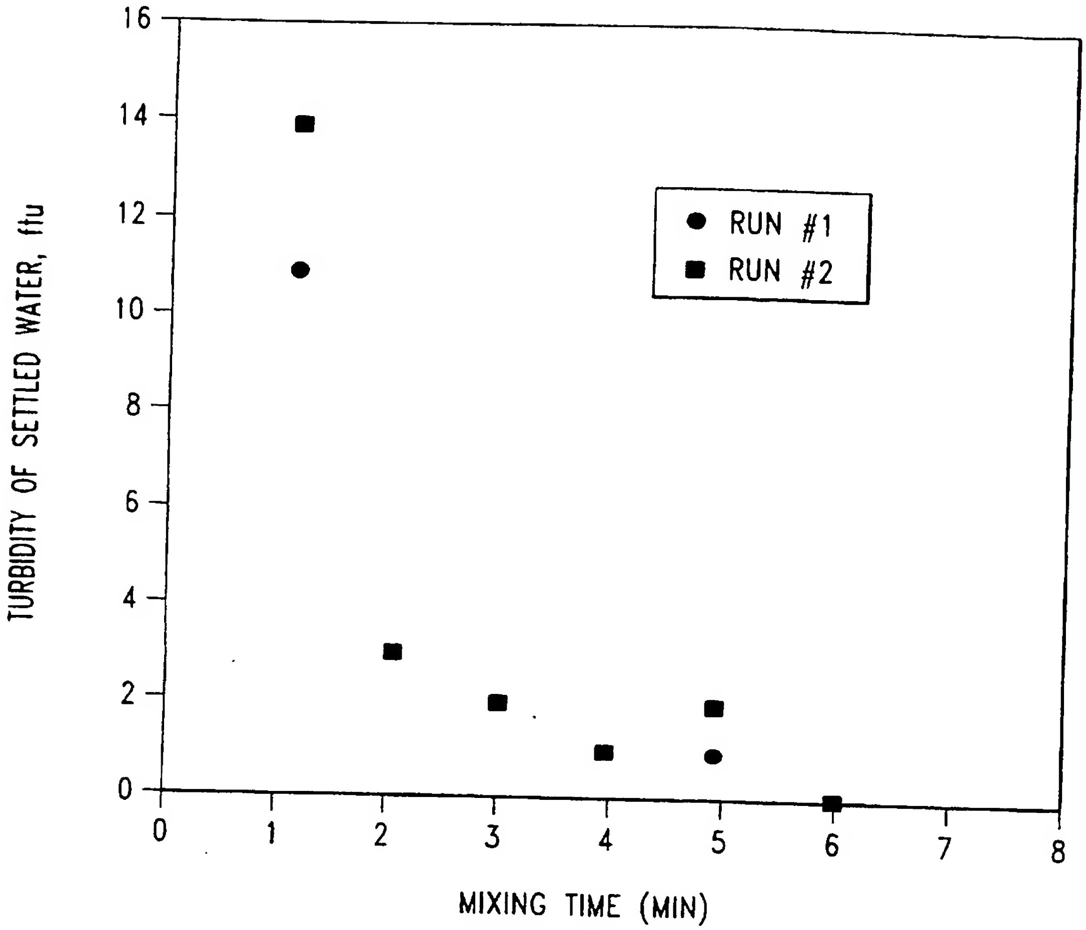

16
14
12
10
8
6
4
2
0
TURBIDITY OF SETTLED WATER, ftu
0
1
2
3
4
5
6
7
8
MIXING TIME (MIN)
RUN #1
RUN #2

Fig. 4

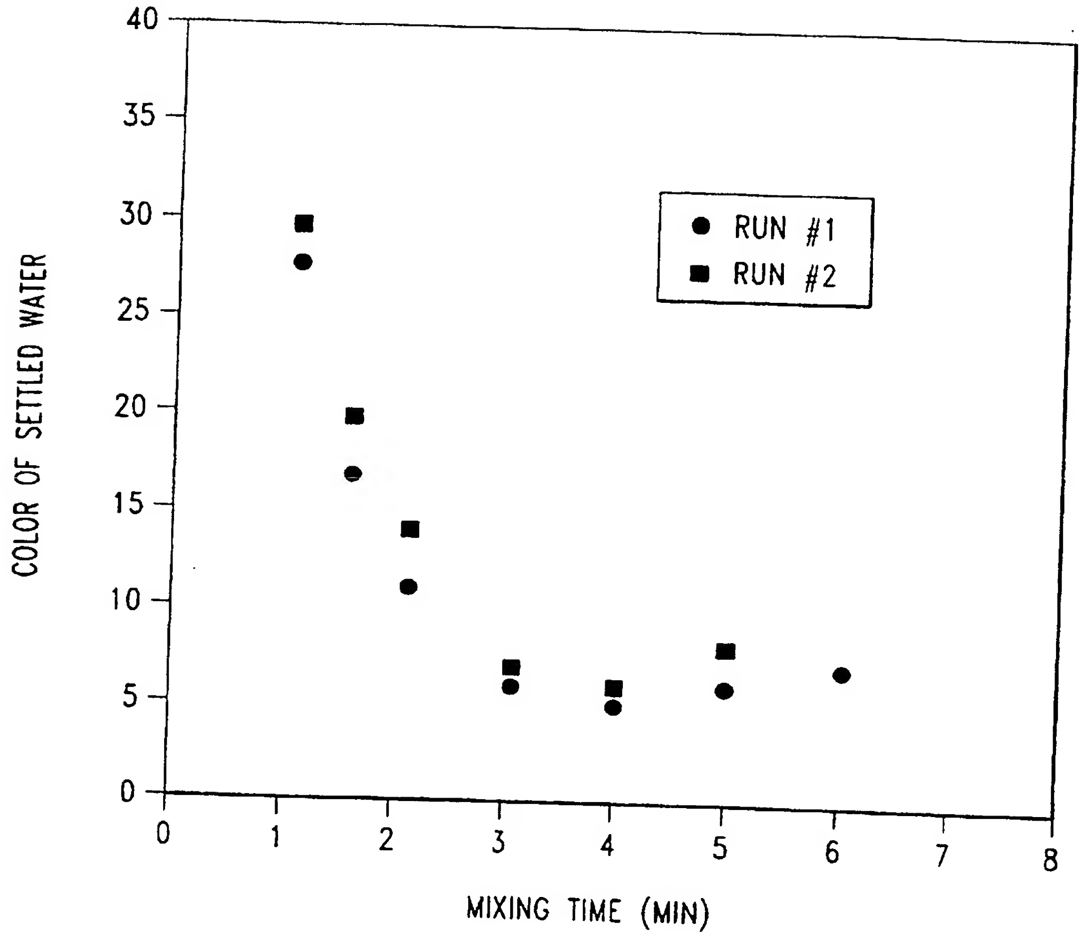

RUN #1
RUN #2
COLOR OF SETTLED WATER
MIXING TIME (MIN)
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8

Fig. 5

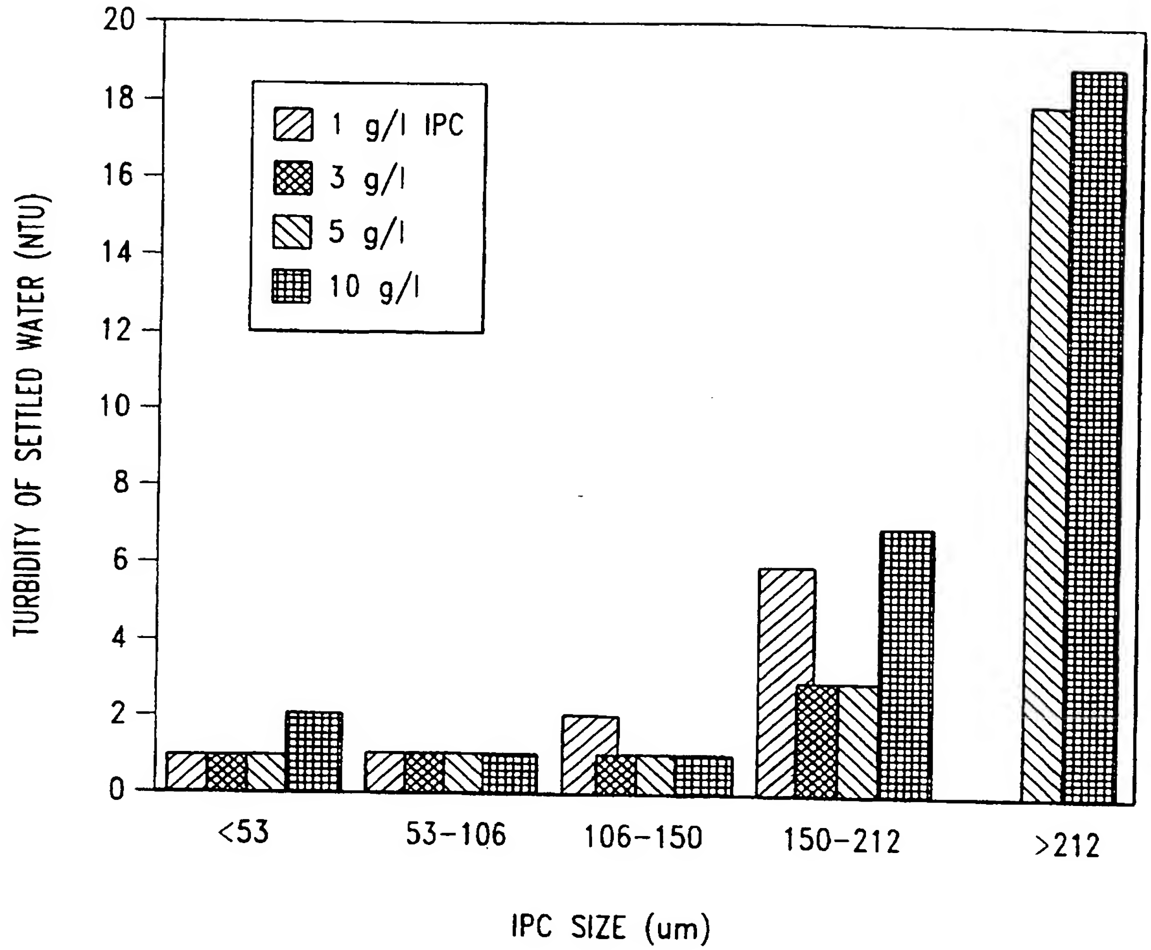

20
18
16
14
12
10
8
6
4
2
0
TURBIDITY OF SETTLED WATER (NTU)
1 g/l IPC
3 g/l
5 g/l
10 g/l
<53
53-106
106-150
150-212
>212
IPC SIZE (um)

Fig. 6

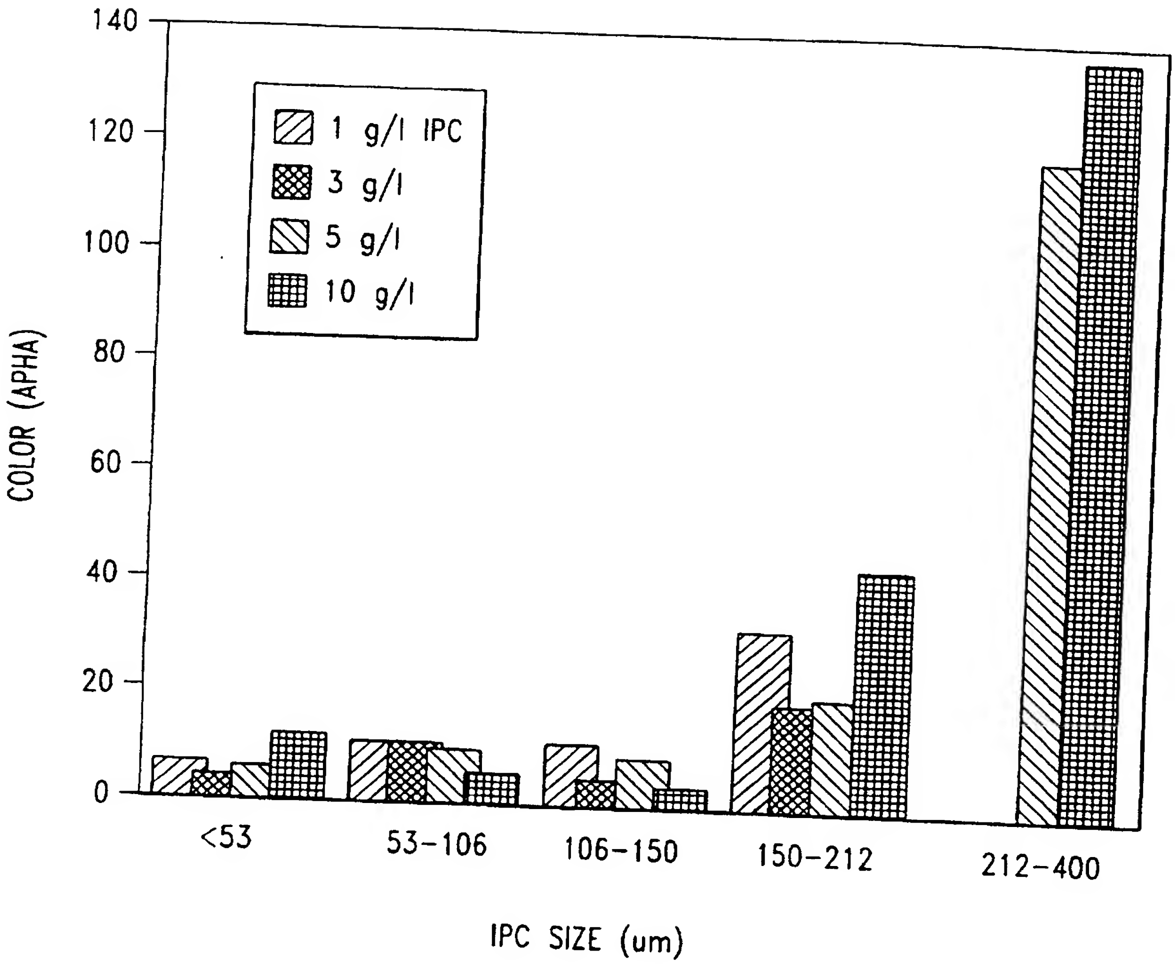
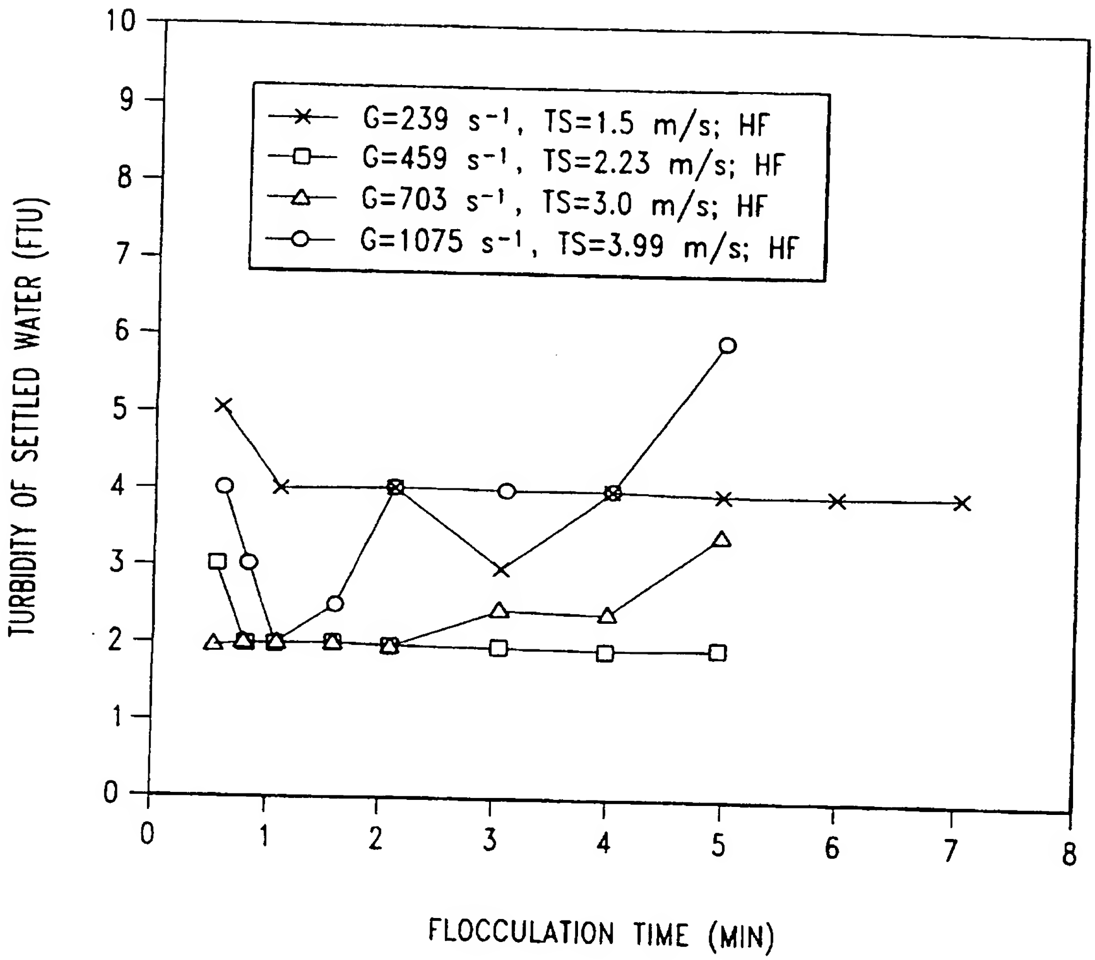

140
120
100
80
60
40
20
0
COLOR (APHA)
1 g/l IPC
3 g/l
5 g/l
10 g/l
<53
53-106
106-150
150-212
212-400
IPC SIZE (um)

Fig. 7



10
9
8
7
6
5
4
3
2
1
0
TURBIDITY OF SETTLED WATER (FTU)
G=239 s⁻¹, TS=1.5 m/s; HF
G=459 s⁻¹, TS=2.23 m/s; HF
G=703 s⁻¹, TS=3.0 m/s; HF
G=1075 s⁻¹, TS=3.99 m/s; HF
0 1 2 3 4 5 6 7 8
FLOCCULATION TIME (MIN)

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/04606

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01D21/00 B01D21/08 B01D21/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 23 01 718 A (SIMMERING-GRAZ-PAUKER AG) 27 June 1974 see page 7, paragraph 2 - page 10, paragraph 2; figures ---	1,2,8, 10,12, 16,17
A	WO 90 09222 A (GOLGONDA) 23 August 1990 see claims; figure 1 ---	1,2,8, 10,12, 16,17
A	US 5 478 468 A (DENO ET AL.) 26 December 1995 see figures 1,2 -----	1,8,16

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
11 July 1997	22.07.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Plaka, T

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 97/04606

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